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Kai

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(54) **COAXIAL WAVEGUIDE CONVERTER AND RIDGE WAVEGUIDE**

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(73) Assignee: **NEC CORPORATION**, Tokyo (JP)

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(51) **Int. Cl.**

H01P 5/103	(2006.01)
H01P 5/08	(2006.01)
H01P 3/00	(2006.01)
H01P 3/123	(2006.01)

(52) **U.S. Cl.**
CPC .. ***H01P 5/08*** (2013.01); ***H01P 3/00*** (2013.01); ***H01P 5/103*** (2013.01); *H01P 3/123* (2013.01)

(58) **Field of Classification Search**
USPC 333/26, 33–34, 254, 260
See application file for complete search history.

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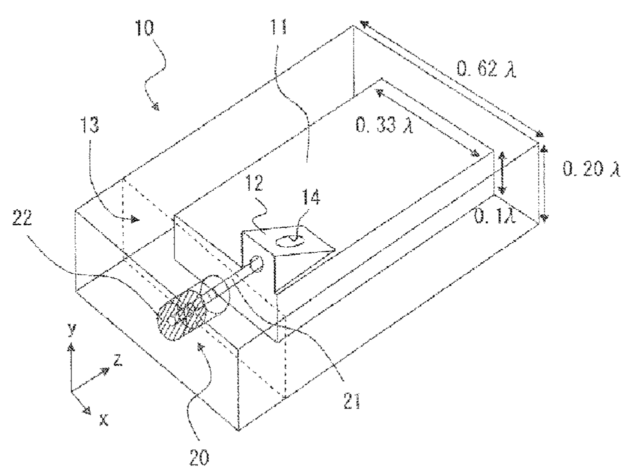
(57) **ABSTRACT**

Provided is a coaxial waveguide converter and a ridge waveguide that are insusceptible to manufacturing variances over a broad bandwidth. The coaxial waveguide converter includes a ridge waveguide (**10**) including a ridge (**11**) and a coaxial line (**20**). A projection (**12**) projecting toward a side of a waveguide space (**13**) is provided in the ridge (**11**), an amount of projection of the projection (**12**) decreases gradually from an end surface of the ridge waveguide (**10**) on a side of the coaxial line along a waveguide direction and an inner conductor (**21**) of the coaxial line (**20**) is inserted in the through-hole (**14**) at a position displaced from a center of the ridge waveguide (**10**) in a direction perpendicular to a direction in which the projection (**12**) projects in the end surface of the ridge waveguide (**10**) on the side of the coaxial line.

9 Claims, 7 Drawing Sheets



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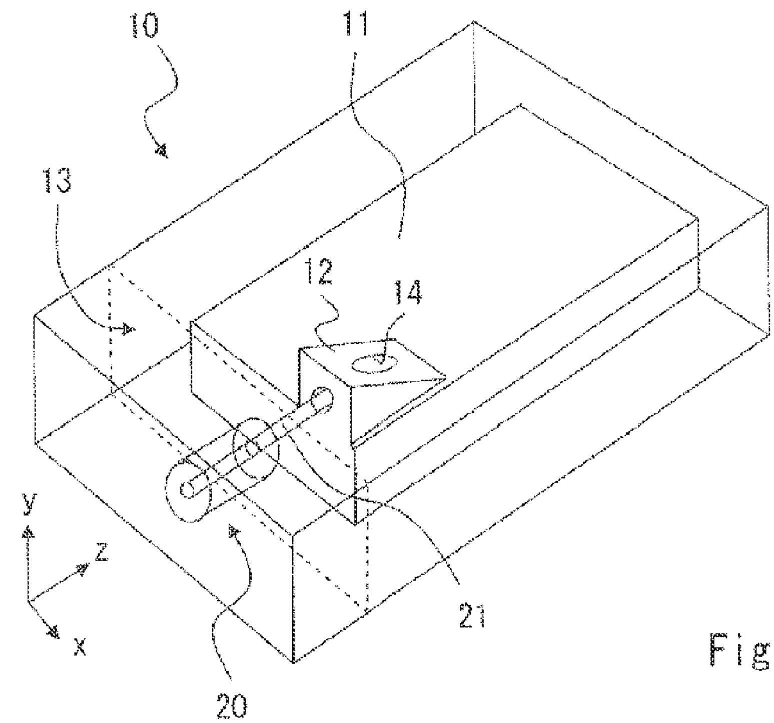

10
11
13
12
14
y
z
x
21
20

Fig. 1

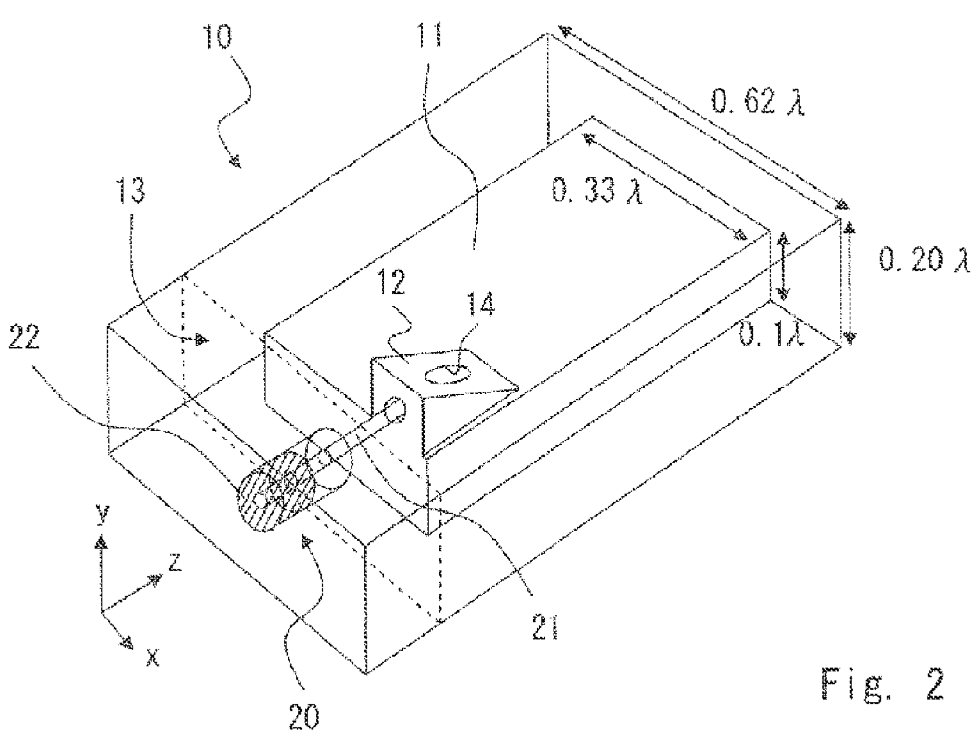

10
11
0.62 λ
0.33 λ
13
0.20 λ
12
14
22
0.1λ
y
z
x
21
20

Fig. 2

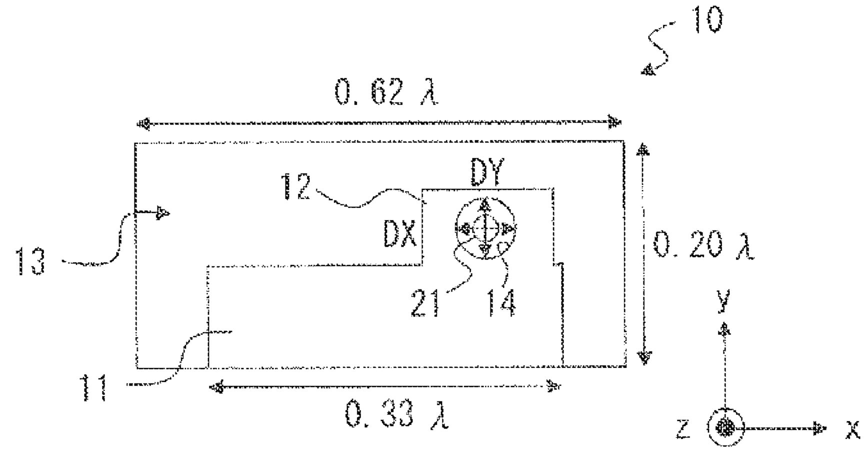

10
0.62 λ
DY
12
DX
13
0.20 λ
21
14
y
11
0.33 λ
z
x

Fig. 3

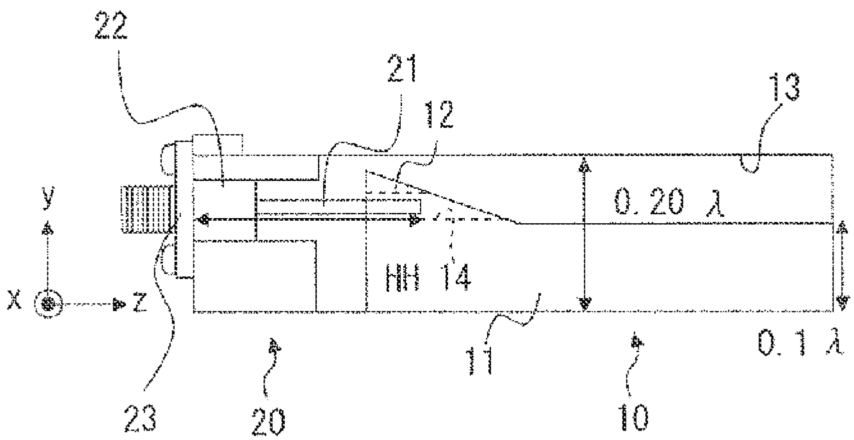

22
21
12
13
y
0.20 λ
HH 14
x
z
11
0.1 λ
23
20
10

Fig. 4

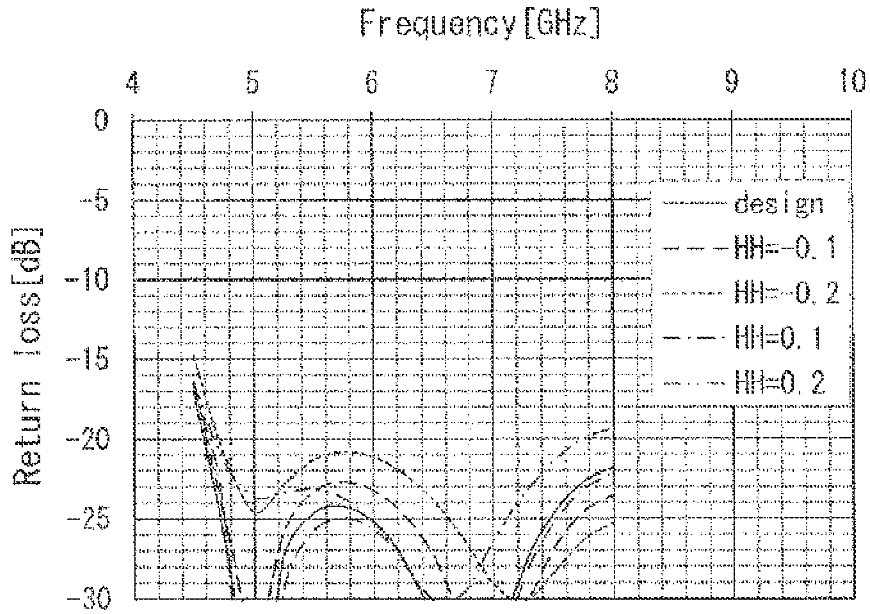

Frequency[GHz]
4
5
6
7
8
9
10
0
-5
-10
-15
-20
-25
-30
Return loss[dB]
design
HH=-0.1
HH=-0.2
HH=0.1
HH=0.2

Fig. 5

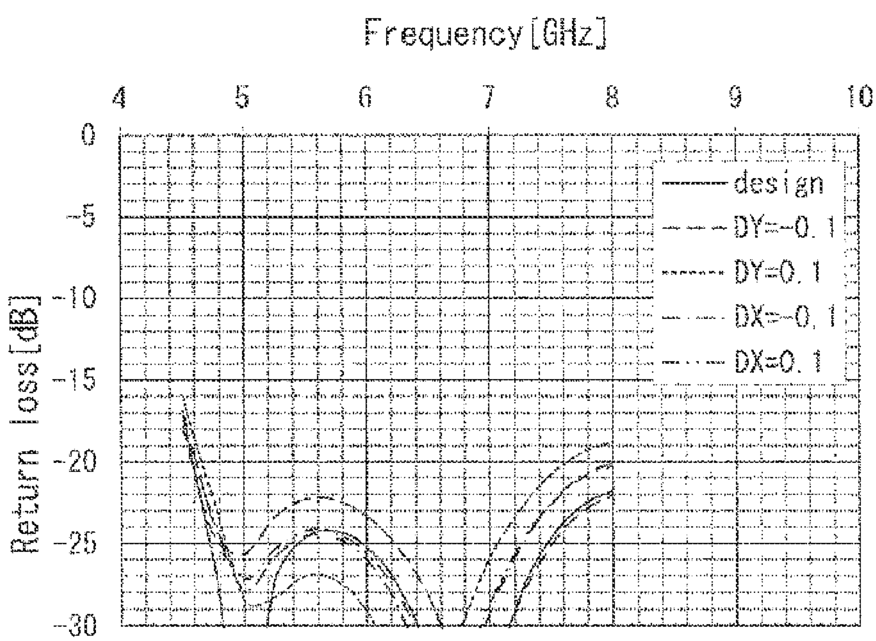

Frequency[GHz]
4
5
6
7
8
9
10
0
-5
-10
-15
-20
-25
-30
Return loss[dB]
design
DY=-0.1
DY=0.1
DX=-0.1
DX=0.1

Fig. 6

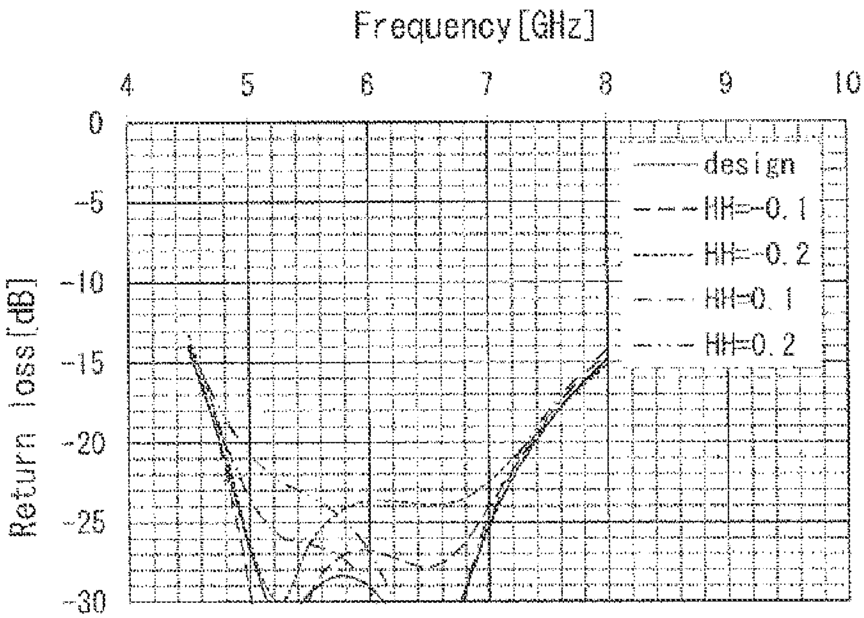

Frequency[GHz]
4
5
6
7
8
9
10
0
-5
-10
-15
-20
-25
-30
Return loss[dB]
design
HH=-0.1
HH=-0.2
HH=0.1
HH=0.2

Fig. 7

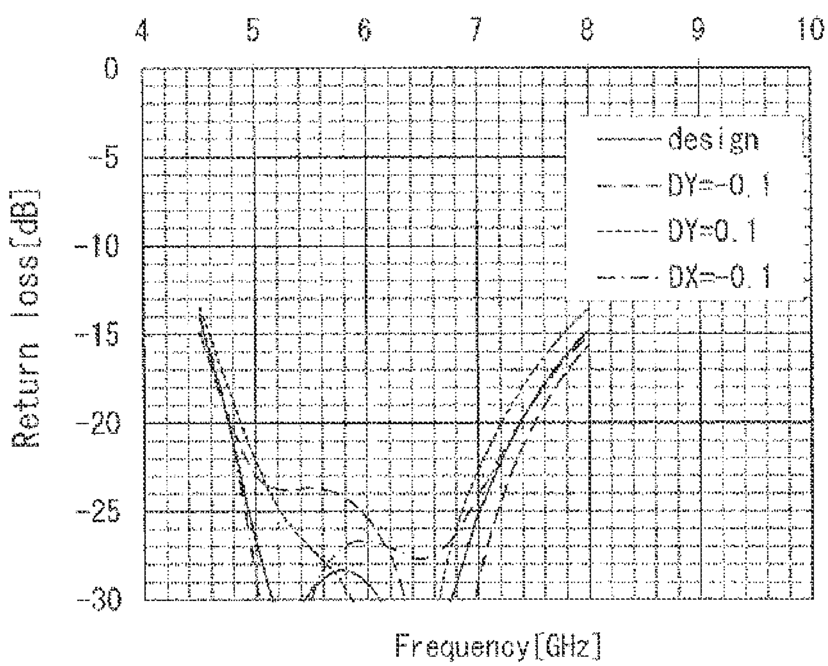

4
5
6
7
8
9
10
0
-5
-10
-15
-20
-25
-30
Return loss[dB]
design
DY=-0.1
DY=0.1
DX=-0.1
Frequency[GHz]

Fig. 8

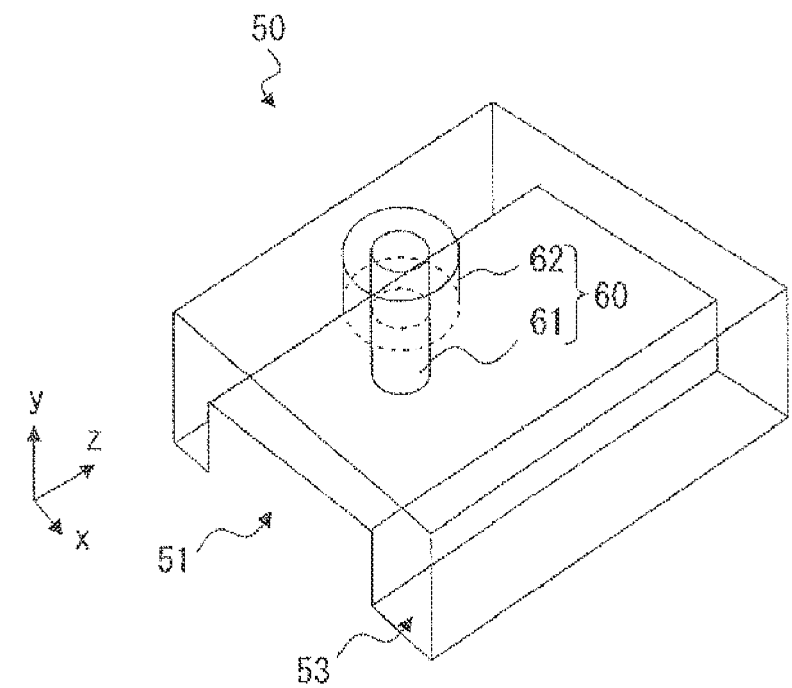


Fig. 9

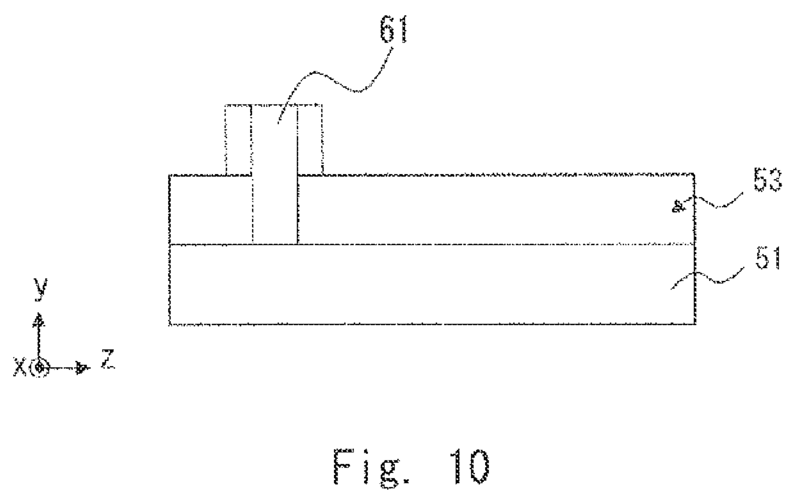
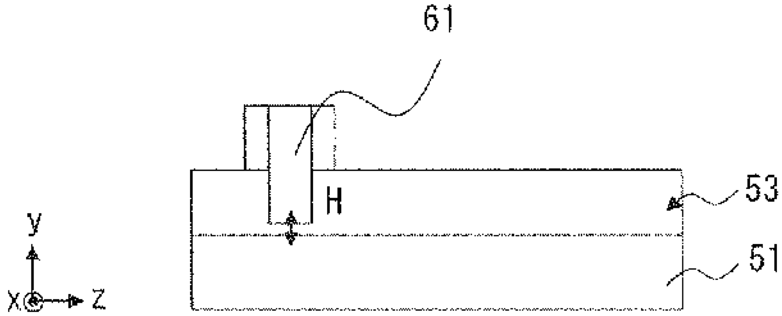
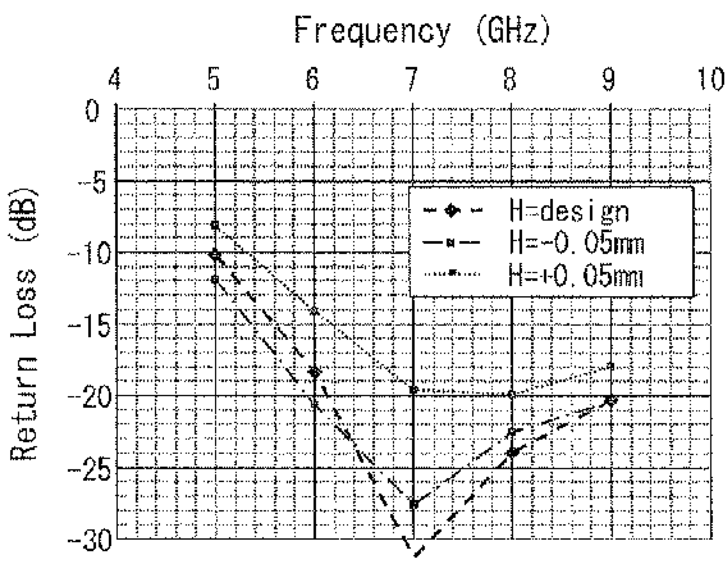


Fig. 10



61
53
51
H
y
X
Z

Fig. 11



Frequency (GHz)
4
5
6
7
8
9
10
0
-5
-10
-15
-20
-25
-30
Return Loss (dB)
H=design
H=-0.05mm
H=+0.05mm

Fig. 12

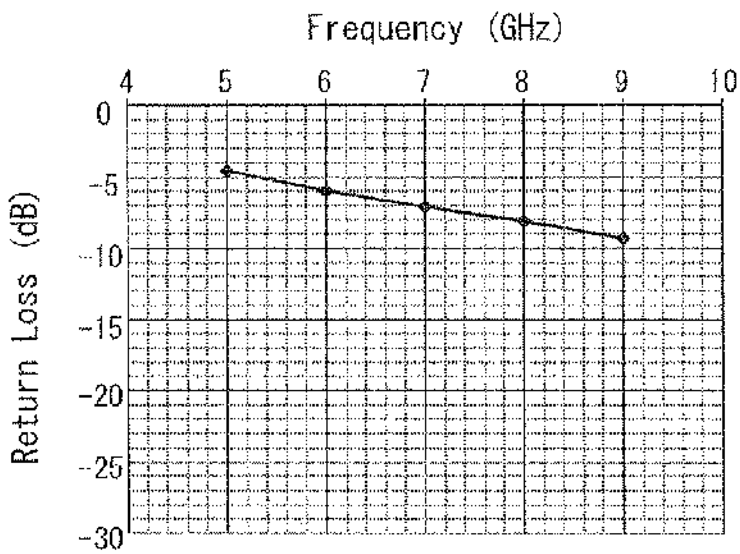


Fig. 13

COAXIAL WAVEGUIDE CONVERTER AND RIDGE WAVEGUIDE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/JP2011/006600 filed Nov. 28, 2011, claiming priority based on Japanese Patent Application No. 2011-012702 filed Jan. 25, 2011, the contents of all of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present invention relates to a coaxial waveguide converter and a ridge waveguide.

BACKGROUND ART

A ridge waveguide has a lower cutoff frequency than a rectangular waveguide, thereby exhibiting broadband transmission characteristics (patent literature 1). Since the ridge waveguide has favorable transmission characteristics also in the low frequency band, the ridge waveguide can be realized in a smaller size than the rectangular waveguide at the same design frequency. Adopting the ridge waveguide as a transmission line of a radio frequency circuit has an advantage of realizing the radio frequency circuit in a physically smaller space at the same design frequency.

CITATION LIST

Patent Literature

Patent literature 1: Japanese Examined Patent Application Publication No. H06-18287

SUMMARY OF INVENTION

Technical Problem

As a converter of the coaxial and ridge waveguide, there is an H-plane coupled configuration in which an inner conductor is inserted from an H-plane. Further, there are a short circuit type and an open circuit type in the H-plane coupled configuration. This configuration is explained using FIGS. **9** to **11**. FIG. **9** is a perspective diagram schematically showing an H-plane coupled coaxial waveguide converter. FIG. **10** is a side view showing a connection configuration of the short circuit type, and FIG. **11** is a cross-sectional view showing a connection configuration of the open circuit type.

As shown in FIG. **9**, an inner conductor **61** of a coaxial line **60** is electromagnetically coupled to a ridge waveguide **50** from an H-plane (magnetic field plane). A dielectric **62** is provided on an outer circumference of the inner conductor **61**. Moreover, a ridge **51** is provided in the ridge waveguide **50**. Then, a waveguide space **52** has a concave shape in its cross section. A configuration in which an end of the inner conductor **61** comes into contact with the ridge **51** is the short circuit type shown in FIG. **10**, while the configuration in which the end of the inner conductor **61** is not in contact with the ridge **51** is the open circuit type shown in FIG. **11**.

In the open circuit type shown in FIG. **11**, the electromagnetic field coupling of the inner conductor **61** strongly depends on capacitance formed between a lower surface of the end of the inner conductor **61** and an upper surface of the ridge waveguide **50**. Therefore, the open circuit type has features in which fluctuation in characteristics associated with a change in H is extremely large. FIG. **12** shows return loss characteristics of a 7 GHz model open circuit type. As shown in FIG. **12**, return loss deteriorates below −20 dB by a change of only 0.05 mm in the distance H between the lower surface of the end of the inner conductor **61** and the upper surface of the ridge waveguide **50**. Therefore, there is a problem in which characteristics greatly deteriorate due to manufacturing variances.

On the other hand, characteristics are stabilized in the short circuit type shown in FIG. **10**. However, the inner conductor **61** is coupled to an electromagnetic field in the ridge waveguide **50** too strongly, thereby hindering impedance matching. Moreover, it is difficult to realize stable electric contact for manufacturing reasons. FIG. **13** shows frequency characteristics of return loss of a 7 GHz model short circuit type. As shown in FIG. **13**, merely inserting the inner conductor **61** to make a connection achieves return loss of only about −7 dB. Further, in the H-plane coupled coaxial waveguide converter, the frequency characteristics strongly depend on a dimension of the inner conductor in order to achieve broadband characteristics. Therefore, a step is often formed in the inner conductor to match impedance, and in many cases, this complicates the configuration for manufacturing reasons.

As has been described, there is a problem in the H-plane coupled coaxial waveguide converter that the H-plane coupled coaxial waveguide converter is susceptible to the manufacturing variances, and thus the characteristics deteriorate.

An objective of the present invention is to provide a ridge waveguide and a coaxial waveguide converter that are unsusceptible to the manufacturing variances over a broad bandwidth.

Solution to Problem

In an exemplary aspect of the present invention, a ridge waveguide having a ridge includes a projection that projects from the ridge toward a side of a waveguide space, in which an amount of projection of the projection decreases gradually from an end surface of the ridge waveguide on a side of a coaxial line along a waveguide direction of the ridge waveguide, a through-hole reaching the waveguide space of the ridge waveguide is provided in the projection, the through-hole is disposed at a position displaced from a center of the ridge waveguide in a direction perpendicular to a direction in which the projection projects in the end surface of the ridge waveguide on the side of the coaxial line, and an inner conductor of the coaxial line is inserted in the through-hole.

In another exemplary aspect of the present invention, a coaxial waveguide converter includes a ridge waveguide having a ridge and a coaxial line that is contactlessly and electromagnetically coupled to the ridge waveguide from an E-plane of the ridge waveguide, in which a projection projecting toward a side of a waveguide space of the ridge waveguide is provided in the ridge of the ridge waveguide, an amount of projection of the projection decreases gradually from an end surface of the ridge waveguide on a side of the coaxial line along a waveguide direction of the ridge waveguide, a through-hole reaching the waveguide space of the ridge waveguide is provided in the projection, and an inner conductor of the coaxial line is inserted in the through-hole at a position displaced from a center of the ridge waveguide in a direction perpendicular to a direction in which the projection projects in the end surface of the ridge waveguide on the side of the coaxial line.

Advantageous Effects of Invention

According to the present invention, it is possible to provide the ridge waveguide and the coaxial waveguide converter that are unsusceptible to manufacturing variances over a broad bandwidth.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective diagram showing a configuration of a coaxial waveguide converter according to an exemplary embodiment of the present invention;

FIG. **2** is a perspective diagram showing the configuration of the coaxial waveguide converter according to a first exemplary embodiment of the present invention;

FIG. **3** is a front elevational view showing the configuration of the coaxial waveguide converter according to the first exemplary embodiment of the present invention;

FIG. **4** is a perspective diagram showing the configuration of the coaxial waveguide converter according to the first exemplary embodiment of the present invention;

FIG. **5** is a graph showing characteristics of the coaxial waveguide converter according to this exemplary embodiment of the present invention;

FIG. **6** is a graph showing characteristics of the coaxial waveguide converter according to this exemplary embodiment of the present invention;

FIG. **7** is a graph showing characteristics of the coaxial waveguide converter when a projection is disposed at the center;

FIG. **8** is a graph showing characteristics of the coaxial waveguide converter when the projection is disposed at the center;

FIG. **9** is a perspective diagram showing a configuration of the coaxial waveguide converter using H plane electromagnetic field coupling;

FIG. **10** is a side view showing a configuration of a short circuit coaxial waveguide converter using the H-plane electromagnetic field coupling;

FIG. **11** is a side view showing the configuration of an open circuit coaxial waveguide converter using the H-plane electromagnetic field coupling;

FIG. **12** is a graph showing characteristics of the coaxial waveguide converter shown in FIG. **10**; and

FIG. **13** is a graph showing characteristics of the coaxial waveguide converter shown in FIG. **11**.

DESCRIPTION OF EMBODIMENTS

An exemplary embodiment of the present invention is explained with reference to the attached drawings. The exemplary embodiment explained below is an example of the present invention, and the present invention is not limited to the following exemplary embodiment. Note that components denoted by the same reference numerals in the specification and drawings indicate the same components.

A configuration of a coaxial waveguide converter according to the present invention is explained using FIG. **1**. The coaxial waveguide converter according to the present invention includes a ridge waveguide **10** having a ridge **11** and a coaxial line **20** that is contactlessly and electromagnetically coupled to the ridge waveguide **10** from an E-plane. A projection **12** projecting toward a waveguide space **13** side of the ridge waveguide **10** is provided in the ridge **11** of the ridge waveguide **10**. The amount of projection of the projection **12** decreases gradually from an end surface on the coaxial line side of the ridge waveguide **10** along a waveguide direction (z direction) of the ridge waveguide **10**. A through-hole **14** reaching the waveguide space **13** of the ridge waveguide **10** is provided in the projection **12**. An inner conductor **21** of the coaxial line **20** is inserted in the through-hole **14** at a position displaced from the center of the ridge waveguide **10** in the direction (x direction) that is perpendicular to the direction (y direction) in which the projection **12** projects in an end surface of the ridge waveguide **10** on the coaxial line side. Then, it is possible to realize a coaxial waveguide converter that is insusceptible to manufacturing variances over a broad bandwidth.

A specific configuration of the coaxial waveguide converter is explained using FIGS. **2** to **4**. FIG. **2** is a perspective diagram schematically showing the configuration of the coaxial waveguide converter. FIG. **3** is a front elevational view showing the configuration of the coaxial waveguide converter. FIG. **4** is a side view showing the configuration of the coaxial waveguide converter. Note that in this example, a three-dimensional orthogonal coordinate system is used for the explanation as shown in FIGS. **2** to **4**. The waveguide direction shall be a z direction, and orthogonal directions that are perpendicular to the waveguide direction shall be x and y directions, respectively. In the following explanation, the x direction shall be a width direction and the y direction shall be a height direction. Moreover, the z direction is a waveguide direction of the ridge waveguide **10**.

The coaxial waveguide converter includes the coaxial line **20** and the ridge waveguide **10**. The coaxial line **20** includes the inner conductor **21** and a dielectric **22**. The inner conductor **21** is provided at the center of the dielectric **22**. Therefore, the circumference of the inner conductor **21** made of metal is surrounded by the dielectric **22**. The inner conductor **21** is contactlessly and electromagnetically coupled to the ridge waveguide **10**. In the part coupled to the ridge waveguide **10**, the inner conductor **21** is disposed along the z direction. Therefore, the inner conductor **21** is inserted in the waveguide space **13** of the ridge waveguide **10** from the E-plane (electric field surface) of the ridge waveguide **10**. Note that the E-plane is a plane parallel to an xy plane.

The ridge waveguide **10** includes the ridge **11**. Then, the waveguide space **13** is formed in an almost concave shape in its cross section, as shown in FIG. **3**. The ridge **11** is disposed at the center of the ridge waveguide **10** in the x direction. Thus, the sizes of both sides of the waveguide space **13** of the ridge **11** in the x direction are equal. The ridge **11** is formed of a conductor such as metal. With the ridge **11** being formed, the ridge waveguide **10** becomes a single waveguide tube. It is obvious that a circumference of the waveguide space **13** is surrounded by an outer conductor (not shown) made of metal.

For example, the width of the waveguide space **13** is 0.62λ, and the height of the waveguide space **13** is 0.20λ. The width of the ridge **11** is 0.33λ, and the height of the ridge **11** is 0.1λ. Note that λ is a wavelength corresponding to a design frequency.

Further, the projection **12** projecting toward the y direction is provided in the ridge **11**. Accordingly, the size of the waveguide space **13** in the y direction is small only in the part where the projection **12** is provided in the x direction. The projection **12** is a rectangular shape on the xy plane shown in FIG. **3**. Then, as shown in FIGS. **2** and **4**, the amount of projection of the projection **12** decreases gradually along the waveguide direction (z direction). In this example, the projection **12** is a triangular shape on a yz plane shown in FIG. **4**.

In other words, the projection **12** is formed in a triangular prism with a surface parallel to the yz plane as a bottom surface. As mentioned above, the projection **12** with its amount of projection gradually decreasing along the waveguide direction is provided in the ridge **11**. As shown in FIG. **4**, the projection **12** has a triangular shape in the side view (yz plane). Then, the surface of the projection **12** can be made flat. This facilitates manufacturing of the ridge waveguide **10**. When the ridge **11** with its cross section being the rectangular shape and the projection **12** with its cross section being the rectangular shape are joined, the joined cross section presents a convex shape.

Furthermore, the projection **12** is disposed displacing from the center of the waveguide space **13** in the x direction. In this example, the projection **12** is displaced in the +x direction from the center of the waveguide space **13**. Therefore, the sizes of the waveguide space **13** on both sides of the projection **12** in the x direction are different. In this example, as shown in FIG. **3**, the waveguide space **13** on the +x side of the projection **12** is smaller than the waveguide space **13** on the −x side.

The through-hole **14** is formed in the projection **12**. The through-hole **14** is disposed at the center of the projection **12** on the xy plane. The through-hole **14** penetrates from the end surface of the ridge waveguide **10** on the coaxial line side to the waveguide space **13**. The inner conductor **21** is inserted in this through-hole **14**. The through-hole **14** is a circular shape on the xy plane. The through-hole **14** is provided in parallel to the z direction. The diameter of the through-hole **14** is about 1.5 times greater than the diameter of the inner conductor **21**. With the diameter of the through-hole **14** being 1.5 times greater than the diameter of the inner conductor, it is possible to prevent the inner conductor **21** from coming into contact with the ridge **11**. That is, the inner conductor **21** will not come into contact with metal even with a slight manufacturing variance. Then, the inner conductor **21** and the ridge waveguide **10** contactlessly and electromagnetically coupled. The through-hole **14** is surrounded by the conductor of the projection **12** on the xy plane.

As shown in FIG. **4**, the coaxial line **20** is connected to the ridge waveguide **10** by a connector **23**. In detail, the connector **23** fixes the coaxial line **20** to the ridge waveguide **10** so that the inner conductor **21** may be inserted in the through-hole **14** from the E-plane (electric field plane) of the ridge waveguide **10**. As the connector **23**, a commercially available SMA connector can be used, for example. Impedance matching can be achieved by parameter searching for an insertion length of the connector **23** and the shape of the projection **12**. In other words, impedance can be matched by adjusting the insertion length of the inner conductor **21** and the shape of the projection **12**. This achieves the impedance matching relatively easily.

The inner conductor **21** of the coaxial line **20** is electromagnetically coupled to the ridge **11** of the ridge waveguide **10**. That is, the inner conductor **21** is RF-coupled to the ridge waveguide **10** via the projection **12**. Electromagnetic field distribution of the ridge waveguide **10** is close to a dual conductor system TEM mode that regards the ridge **11** as the inner conductor **21**. As the ridge waveguide **10** has a lower cutoff frequency, the ridge waveguide **10** is used as a transmission line over a broad bandwidth. Electromagnetic field distribution in the cross section of the ridge waveguide **10** resembles electromagnetic field distribution of the coaxial line **20**. For this reason, when the inner conductor **21** of the coaxial line **20** is electromagnetically coupled to the ridge **11** of the ridge waveguide **10**, impedance matching can be achieved relatively easily.

Moreover, the position where the inner conductor **21** is electromagnetically coupled to the ridge **11** is displaced from the center of the ridge waveguide. Specifically, the through-hole **14** is disposed at a position displaced from the center of the ridge waveguide **10** in the direction (x direction) that is perpendicular to the direction (y direction) in which the projection **12** projects in the end surface of the ridge waveguide **10** on the coaxial line **20** side. Then, a frequency at which double resonance occurs in the impedance can be moved. Appropriately choosing the position of the through-hole in this way allows an increase in the bandwidth more than when the projection **12** is disposed at the center.

This further reduces the deterioration in the characteristics due to the manufacturing variances. Specifically, deterioration in the return loss characteristics can be prevented even when the manufacturing variances occur. For example, the manufacturing variances in the through-hole **14** shall be DX and DY. As shown in FIG. **3**, DX is displacement from the center of the through-hole **14** at the center of the inner conductor **21** in the x direction, and DY is displacement from the center of the through-hole **14** at the center of the inner conductor **21** in the y direction. That is, when the center of the through-hole **14** and the center of the inner conductor **21** match on the xy plane, DX and DY are zero. Additionally, as shown in FIG. **4**, the insertion length of the inner conductor **21** shall be HH. When the insertion length HH is displaced from a design value, an end position of the inner conductor **21** is displaced from a design value. These variances are prone to occur at the time of manufacturing.

The characteristics of the coaxial waveguide converter according to this exemplary embodiment are explained using FIGS. **5** to **8**. FIGS. **5** and **6** are graphs showing frequency characteristics of return loss of the coaxial waveguide converter according to this exemplary embodiment. FIGS. **7** and **8** are diagrams showing frequency characteristics of the return loss when the projection **12** is disposed at the center of the waveguide space **13** in the x direction in the coaxial waveguide converter shown in FIGS. **2** to **4**. FIGS. **5** and **7** show frequency characteristics along with changes in HH from the design value. Moreover, FIGS. **6** and **8** show frequency characteristics along with changes in DX and DY from the design values. The frequency characteristics of the return loss of a 6.5 GHz band model are explained here.

In the coaxial waveguide converter according to this exemplary embodiment, the return loss will not deteriorate below −20 dB even with twice or more of the manufacturing variance value in H. Similarly, in the coaxial waveguide converter according to this exemplary embodiment, the return loss will not deteriorate below −20 dB even with twice or more of the manufacturing variance values in DX and DY. It is possible to prevent the return loss from deteriorating in this way even when the inner conductor **21** is displaced from the center of the through-hole **14**. In addition, with comparison in the fractional bandwidth with the return loss being lower or equal to −20 dB, the fractional bandwidth are about 30% when the projection **12** is disposed at the center, while the fractional bandwidth are about 45% with the configuration according to the present invention. Thus, further broadband characteristics can be realized.

In the ridge waveguide **10**, the inner conductor **21** of the coaxial line **20** is inserted into the ridge waveguide **10** from the E-plane. Then, the ridge **11** and the inner conductor **21** are contactlessly and electromagnetically coupled. This realizes the coaxial waveguide connection converter that is insusceptible to the manufacturing variances and also over a broad bandwidth.

Furthermore, the inner conductor of the coaxial line **20** inserted into the ridge waveguide **10** from the E-plane is contactlessly and electromagnetically coupled to the projection **12** projecting from the ridge **11**. A hole with a diameter 1.5 times greater than the diameter of the inner conductor **21** is provided in the projection **12**. This assures prevention of contact between the inner conductor **21** and the projection **12**. The projection **12** is disposed at a position displaced from the center of the ridge waveguide **10** in the x direction, as shown in FIG. **3**.

Impedance matching is achieved mainly by the insertion length of the inner conductor **21** and the shape of the projection **12**. The diameter of the inner conductor **21** can be designed using the size of a common SMA connector. More specifically, the size of the through-hole **14** can be designed with the size to allow the inner conductor **21** used for the SMA connector to be inserted in the through-hole **14**. As described above, this realizes broadband characteristics of about 45% in the band of the return loss less than or equal to −20 dB even when the manufacturing variances occur. Since the coaxial waveguide converter according to this exemplary embodiment can be contactlessly connected, characteristics can be stabilized. Furthermore, as the coaxial waveguide converter is insusceptible to the manufacturing variances, the coaxial waveguide converter has great potential as a standard connection circuit configuration.

Although the present invention has been explained with reference to the exemplary embodiment so far, the present invention is not limited by above. Various modifications understandable by a person skilled in the art within the scope of the invention can be made to the configurations and details of the present invention.

The present application claims priority rights of and is based on Japanese Patent Application No. 2011-12702 filed on Jan. 25, 2011 in the Japanese Patent Office, the entire contents of which are hereby incorporated by reference.

INDUSTRIAL APPLICABILITY

The coaxial waveguide converter according to the present invention can be applied to a connection part of a RF (Radio Frequency) transmission/reception separating circuit in an input unit of a simple wireless device.

REFERENCE SIGNS LIST

10 RIDGE WAVEGUIDE
11 RIDGE
12 PROJECTION
13 WAVEGUIDE SPACE
14 THROUGH-HOLE
20 COAXIAL LINE
21 INNER CONDUCTOR
22 DIELECTRIC
23 CONNECTOR
50 RIDGE WAVEGUIDE
51 RIDGE
53 WAVEGUIDE SPACE
60 COAXIAL LINE
61 INNER CONDUCTOR
62 DIELECTRIC

The invention claimed is:

1. A coaxial waveguide converter comprising a ridge waveguide including a ridge, the ridge waveguide comprising:

a projection on a top surface of the ridge that projects from an end of the ridge on a side of a coaxial line toward a side of a waveguide space between a waveguide and the ridge, wherein

an amount of projection of the projection decreases gradually from the end of the ridge on the side of the coaxial line along a waveguide direction of the ridge waveguide,

a through-hole parallel to the top surface of the ridge reaching the waveguide space of the ridge waveguide is provided in the projection,

the through-hole is disposed at a position displaced from a center of the ridge waveguide in a direction perpendicular to a direction in which the projection projects from the end of the ridge on the side of the coaxial line, and

an inner conductor of the coaxial line is inserted in the through-hole.

2. The ridge waveguide according to claim **1**, wherein the projection is a triangular shape in a side view including the waveguide direction.

3. The ridge waveguide according to claim **1**, wherein the projection is a rectangular shape on the end of the ridge on the side of the coaxial line.

4. The ridge waveguide according to claim **3**, wherein the through-hole is disposed at a center of the projection on the end of the ridge on the side of the coaxial line.

5. A coaxial waveguide converter comprising:

a ridge waveguide including a ridge; and

a coaxial line that is contactlessly and electromagnetically coupled to the ridge waveguide from an E-plane of the ridge waveguide, wherein

the ridge comprises a projection on a top surface of the ridge projecting toward a side of a waveguide space of the ridge waveguide between a waveguide and the ridge from an end of the ridge on a side of the coaxial line,

an amount of projection of the projection decreases gradually from the end of the ridge on the side of the coaxial line along a waveguide direction of the ridge waveguide,

a through-hole parallel to the top surface of the ridge reaching the waveguide space of the ridge waveguide is provided in the projection, and

an inner conductor of the coaxial line is inserted in the through-hole at a position displaced from a center of the ridge waveguide in a direction perpendicular to a direction in which the projection projects from the end of the ridge on the side of the coaxial line.

6. The coaxial waveguide converter according to claim **5**, wherein the projection is a triangular shape in a side view including the waveguide direction.

7. The coaxial waveguide converter according to claim **5**, wherein the projection is a rectangular shape on the end of the ridge on the side of the coaxial line.

8. The coaxial waveguide converter according to claim **5**, wherein the through-hole is disposed at a center of the projection on the end of the ridge on the side of the coaxial line.

9. The coaxial waveguide converter according to claim **5**, wherein a diameter of the through-hole is 1.5 times greater than a diameter of the coaxial line.

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